Background
Rendering hair

Important for variety of industries

- Animation movie industry: to render realistic hairs in a physically accurate way.
- Game industry: enhance realism and visual effects.
- Clothes manufacturing industry: to render custom fabrics and to compare appearance in different lighting conditions.
- Hair styling: render hair styling products applied to the hair.

Rendering hair
Hair fiber representation

Explicit representation vs. Implicit representation

- Explicit representation represents each fiber by geometric primitives (e.g. triangles)
- Implicit representation represents fiber

There are a couple of ways to represent hair fibers:

- Connected triangle strips
- Cylindrical primitives
- Trigonal prisms
- Ribbons

Rendering hair
Rendering challenges

Human hair consists of over hundreds of thousands of hair strands. Leads to rendering challenges:

- Memory consumption: to store all fibers in memory.
- Time: rendering realistic scattering effects requires tracing many samples through the hair volume.
- Aliasing: Hair fibers are very thin, requiring additional samples to be drawn to prevent aliasing.

Mathematical notation
Radiometry

- Power (Watts): energy in Joules per second.
- Radiant intensity (steradians): power divided by the solid angle.
- Irradiance (Watts per m^2): power per unit area.
- Radiance : Irradiance per solid angle, where solid angle goes to zero (becoming a ray instead of a cone).

Mathematical notation
Scattering equations

Scattering is represented by a bidirectional reflection distribution function (BRDF):

$$f_r(p, \omega_o, \omega_i) = \frac{dL_o(p, \omega_o)}{dE(p, \omega_i)} = \frac{dL_o(p, \omega_o)}{L_i(p, \omega_i) \cos \theta_i d\omega_i} \tag{1}$$

The BRDF is the fraction of outgoing radiance in direction ω_o related to the incident irradiance from direction ω_i.

Mathematical notation
Hair fibers

- Hair fibers do have cuticle scales oriented at approximately 7 degrees.
- The core of the fiber (medulla and cortex) consist of pigment which absorbs specific wavelengths in the light.
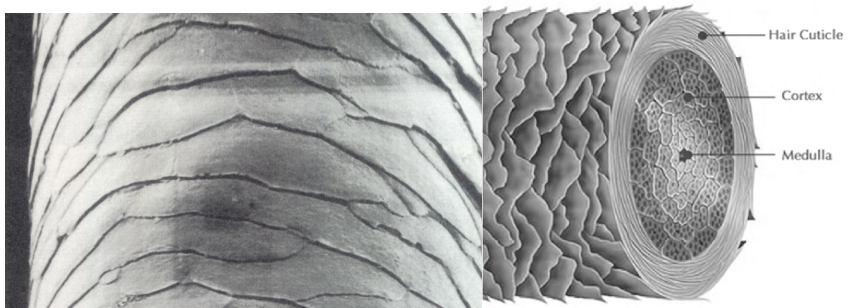
Mathematical notation
Curve scattering equation

- Hair fibers are rendered implicitly by 3D curves.
- Curves have no surface area. They have a length, requiring a change to the BRDF formulation.

$$f_r(p, \omega_o, \omega_i) = \frac{dL_o(p, \omega_o)}{dE(p, \omega_i)} = \frac{dL_o(p, \omega_o)}{L_i(p, \omega_i) \cos \theta_i d\omega_i} \tag{2}$$

The BRDF is the fraction of outgoing radiance in direction ω_o related to the incident irradiance from direction ω_i.

Monte-Carlo integration

Multiple importance sampling

Related work

Structure of hair

Related work

Marschner model

Related work

Dualscattering Approximation

Approach

Goals

Implementation
PBRT

Implementation

Voxel grid

Implementation

Memory and speed requirements

Results

Conclusion